"Falsificability" is basic concept in philosophy of science.

However, we should also say that - since we have the scientific method - no "turkey" died.

Theories which could be in principle be falsified but were not falsified in a series of independent measurements, hold up to now! In a daily-life language we can call them 'verified theory'....

Example: Newton's gravitation!

It is in the typical man-like energy intervals a very good model of reality.

Although we know that it cannot reproduce the physics of very heavy gravitation fields, it can be considered as a low-energy limit (ie effective theory) of gravitation.

For theories which have been not falsified in a variety of situations (although they could have been) R. Dawkins uses the world

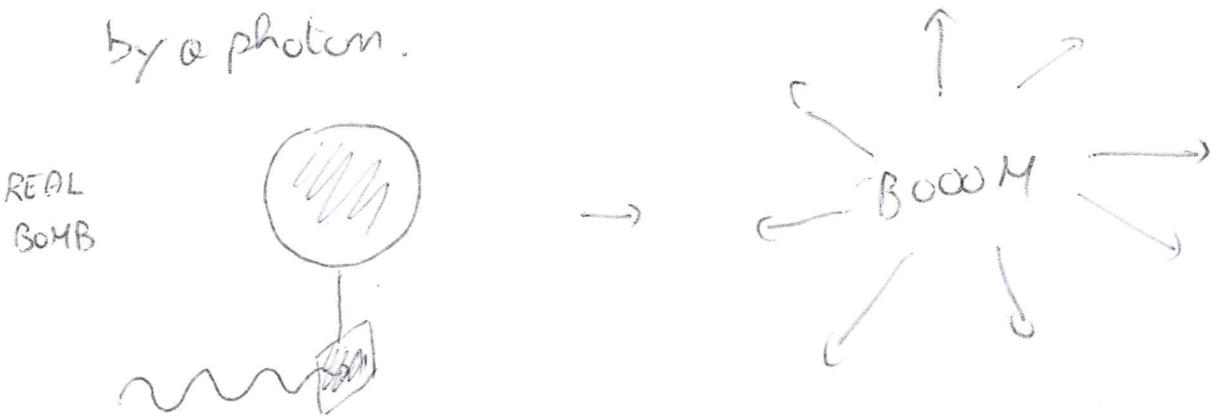
THEORUM

Examples: gravitation, but also (outside physics) evolution.

THE BOMB

(from Elitzur - Vaidman, Foundations of Physics, Vol 23 No 7, 1993)

We have a box full of bombs, which are activated by a photon.



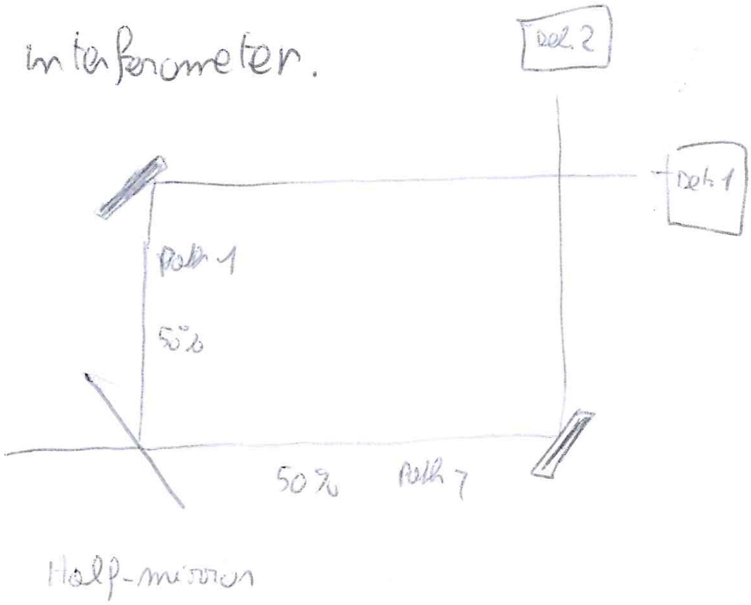
However, some of the bombs are 'dulls'... they are full of sand and the detectors simply leave the photon pass..

How can we be sure to isolate some real bombs, without making it explode?

Clearly, to use a photon does not help: if the bomb was good, it explodes.. and is lost. If it was fake, it doesn't.. in this way we cannot isolate good bombs.

The problem is 'solvable' in the framework of QM.
Although not all, we can save some of the good bombs without letting them explode.

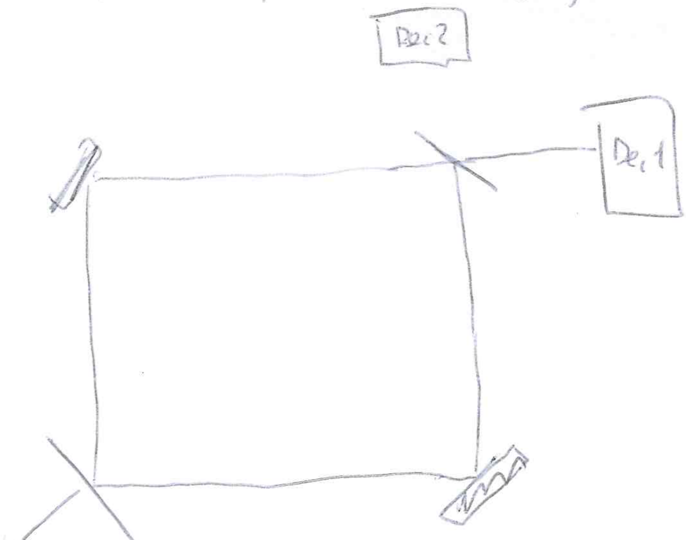
To this end we need to understand the Mach-Zender interferometer.



If Det. 1 makes 'click' $\mapsto$ path 1 was chosen.

If Det. 2 " " $\longrightarrow$ " 2 " "

Now, let us put another half-mirror.



We can prepare the interferometer in such a way that:

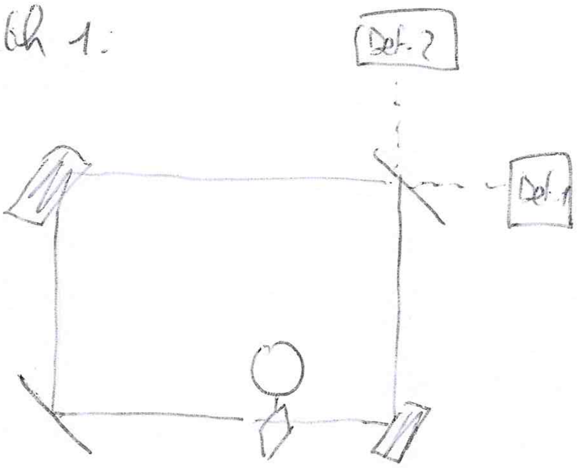
Det. 1 : Constructive interf.
It makes always 'click' there

Det. 2 : destructive interf.
it never makes 'click'.

The wave function of the single photon splits into two parts which then travel along path 1 and path 2 respectively.
Finally, the two parts of the wave function reconnect on the 2° half mirror in such a way that only Det. 1 is activated.

This situation holds true as long as it is impossible to know which path (1 or 2) the photon has taken...
No counter on path 1 (or 2) has been placed.

Now, instead of the counter let us place the bomb on path 1:



Now, we have the following possibility:

The bomb is fake → No 'measurement' → only det. 1 makes a click!

The bomb is true → 50% of the times → it explodes (when path 1 is chosen)
→ 25% → click in Det. 1
→ 25% → click in Det. 2

In the latter 25% of cases we can be sure that the bomb is good and that it did not explode! → $\boxed{\text{Interaction - free MEASUREMENT}}$

We can put it aside.

Then, in the 25% of cases in which Det. 1 makes click we do not know if the bomb was true or fake.

We can however repeat the procedure with all the fake and true non-exploded bombs... if N is the no of good bombs, by iteration we can save

$$\text{no of saved bombs} = \frac{N}{4} + \left(\frac{N}{4}\right)\cdot\frac{1}{4} + \frac{N}{16}\cdot\frac{1}{4} + \dots$$

$$N\sum_{n=1}^{\infty}\left(\frac{1}{4}\right)^n = N\left(\sum_{n=0}^{\infty}\left(\frac{1}{4}\right)^n - 1\right) = N\left(\frac{1}{1-\frac{1}{4}} - 1\right)$$

$$= N\left(\frac{4}{3} - 1\right) = \frac{N}{3}$$

(By slightly modifying the properties of the interferometer one can save up to 50% of the good bombs).

UNCERTAINTY RELATION

We shoul distinguish the two following quantities:

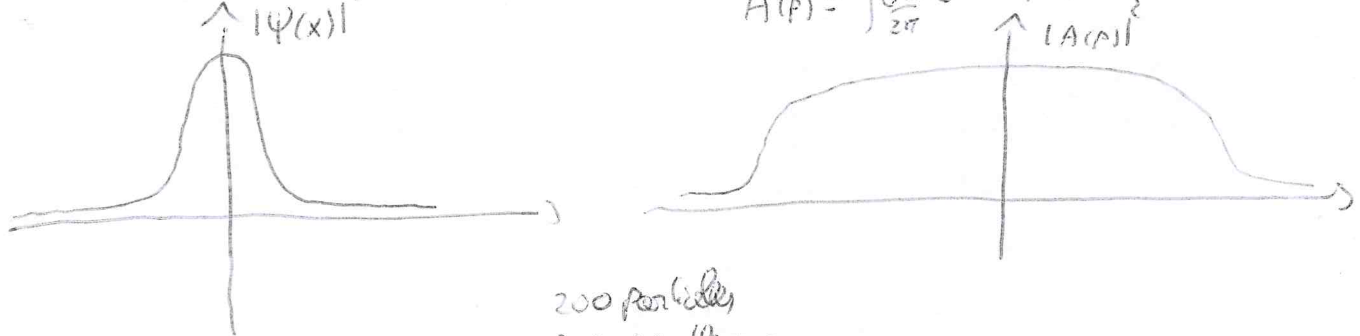
$\delta x \to$ error of the position when performing a measurement

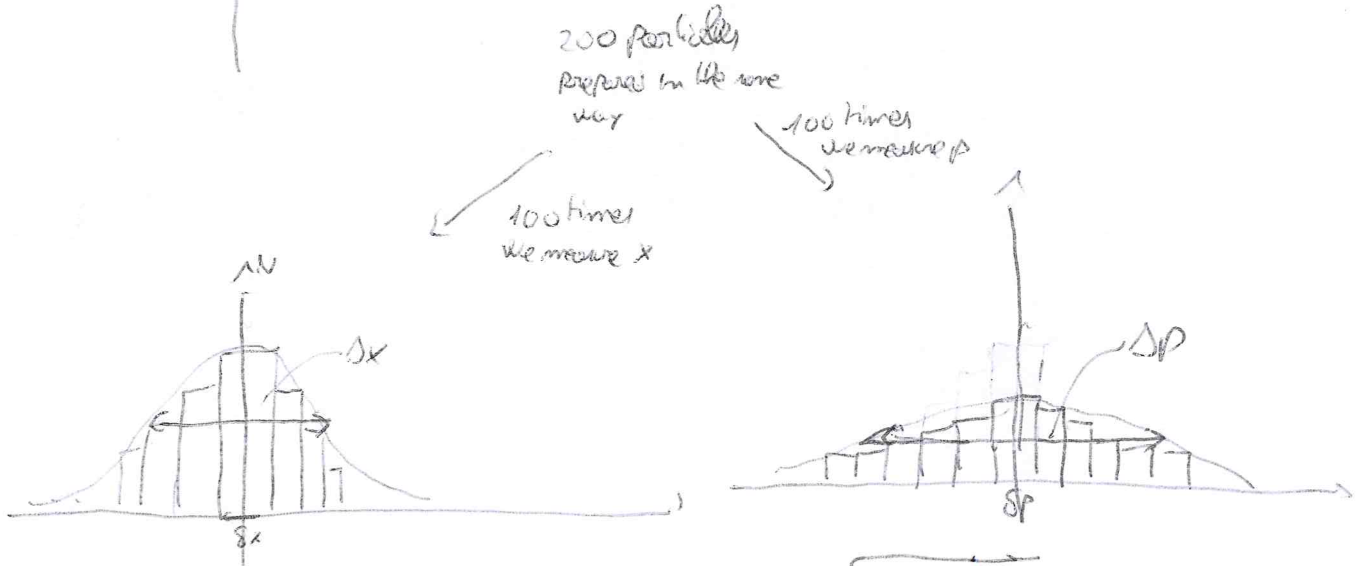
$\Delta x \to$ standard deviation : $(\Delta x)^2 = \langle x^2 \rangle - \langle x \rangle^2$

$$\underset{\substack{\text{1-dim.}\\\text{problem}}}{=} \int_{-\infty}^{\infty} dx\, x^2 |\psi(x)|^2 - \left(\int_{-\infty}^{\infty} dx\, x |\psi(x)|^2 \right)^2$$

The uncertainty deviation derived in QM refer to the standard deviations. It should be better called as "statistical dispersion relation".

$$A(p) = \int \frac{dx}{2\pi} e^{ipx} \psi(x)$$





$\Delta p = \sqrt{\langle p^2 \rangle - \langle p \rangle^2}$

In this way I measure

$\Delta x = \sqrt{\langle x^2 \rangle - \langle x \rangle^2}$! standard deviation!

This is possible if: $\delta x \ll \Delta x$

The uncertainty relation derived in QM refers to the statistical uncertainties Δx and Δp:

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

<u>But note</u>: we did not measure $\hat{x}$ and $\hat{p}$ of one single particle! We have either measured $\hat{x}$ (50% of cases) or $\hat{p}$ (50% of case.

<u>Note also</u>: it is indeed not possible, through two direct measurement of $\hat{x}$ an $\hat{p}$ respectively, to determine x and p.
in fact, if we first measure x, the wf collapses instantaneously to a new wf...
Then, when we measure $\hat{p}$, we actually measure the momentum of a different wave function...